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## TRANSFORMATIONS OF URBAN ELECTRIC TRANSPORT IN UKRAINE AFTER 1991 IN THE VIEW OF TRANSPORT POLICY

**Abstract.** The article presents, in a multifaceted manner, the changes that occurred in urban electric transport in Ukraine after 1991. The purpose of the article is to research the diversification of the degree and directions of development and transformation of urban electric transport systems in the context of the transport policy. The legal and financial conditions for the functioning and development of the system are discussed, and a SWOT analysis of the current situation is carried out. In order to assess the direction of the changes occurring on individual networks, a synthetic index was used, constructed on the basis of the statistical data from 25 years available. The research has shown that in 1991–2016, in the vast majority of Ukrainian cities there was a regression in urban electric transport, the largest in the east of Ukraine. That was of a bipartite nature: in the first years it practically applied to all networks, later a polarization in cities occurred – in parts of cities the situation of urban electric transport has improved slightly. In the context of numerous diagnosed problems, the challenges faced by urban electric transport in Ukraine were indicated.

**Key words:** Ukraine, urban electric transport, tramway, trolleybus, transport policy, economic transformation, electromobility.

### 1. INTRODUCTION

The organization of public transport in Ukraine differs significantly from the solutions applied in the countries of Central and Western Europe. The public transport system consists of two competing subsystems: urban electric transport, and bus transport, mainly marshrutkas (lines of private companies served by low-capacity

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buses), and sometimes additional bus routes operated by cities. The present model of the organisation of urban electric transport in Ukraine is a consequence of the model of the organisation of public transport in the USSR.

Generally, in the USSR, the state at the central level assured rolling stock delivery. Cities through their companies organised public transport using that rolling stock, e.g. planned routes and timetables. Important infrastructure investments were planned and financed at the central level. Public transport consisted of the metro, trams, trolleybuses and buses but in the largest cities there also operated marshrutkas on commercial terms. In the 1990s communal bus companies or bus divisions of communal companies in Ukraine were privatised. The new owners exchanged large buses for smaller vehicles, which are cheaper to use. The privatisation of the bus system has led to the development of the marshrutkas system.

Municipal electric transport is part of a common transport system, designated for the carriage of citizens by trams, trolleybuses and metro trains, according to the needs of residents (*Zakon Ukrainy pro miskyj elektrychnyj transport* 2004). Theoretically, the same function in the public transport system is performed by marshrutkas. However, they operate under market conditions. This means that marshrutkas operate only on routes and only in hours that guarantee a sufficient number of passengers ensuring profitability. In many cases they operate on the same routes as trams and trolleybuses, competing with them for passengers. The commercial model of the marshrutkas system does not satisfy all the needs of residents in terms of mobility evenly.

The shaping of urban electric transport is not solely and exclusively limited to the issue of pragmatism that ensures municipal spatial mobility. In the face of growing ecological challenges, it has become a time requirement and it influences the positioning of Ukrainian cities on the European and on the global scale. The current standards of a modern city require efficient and environmentally neutral transport (e.g. Gonzalez-Feliu, 2013; Laterrasse, 2018; Schiller and Kenworthy, 2018). The environmental challenges of Ukraine are significant and they represent one of the most complex areas for the country to address, given the pressures of continuous economic growth and social transition (Dvulit and Bojko, 2014).

One may also look at the issue of urban electric transport in a broader context – regional or local development. The general assumptions of the system that represent the position of the state on transport policy shall be regarded as a macro approach affecting regional development. Concrete implementations at the level of individual cities affect the efficiency of these centres, as well as determine the living conditions therein. As a consequence, they are part of the local development process.

The transport policy refers to the theory of the basic product by H. Innes, which explains long-term factors of economic growth. It indicates the succes-

sive specialisation of selected products and the competitiveness thereof on foreign markets. The benefits of a specialisation are revealed by improving the organisation of production and reducing the costs of commercial transactions (Landes, 2000). The role of public authorities is to strengthen the specialisation trend, to invest in infrastructure (transport, telecommunications), as well as to support institutions in the educational, service, financial, and consulting dimensions (Maliza and Feser, 1999; Grosse, 2002).

The purpose of the article is to research the diversification of the degree and directions of the development and transformation of urban electric transport systems in Ukrainian cities after 1991 in the context of the transport policy. The article is a continuation of a research conducted by Tarkhov *et al.* (2010) in the field of trends in the transformation of urban electric transport systems in Ukraine. The authors of this article began research in 1991, i.e. in the year when Ukraine regained independence. The analyses on a nation-wide scale have focused not only on the changes taking place in individual networks, but also a wider perspective was employed to look at the directions of transport policy set by the state, as well as the consequences thereof in relation to urban electric transport.

As a research area, the authors assumed the borders of Ukraine from before the conflict of 2014, including both the Crimea and the eastern parts of the Donetsk and Luhansk oblasts. There were historically 32 electric tram networks in this area, until the end of 2018 there were 19 networks active, 10 networks were liquidated (after 1991 – solely Kostiantynivka), 3 closed networks are preserved (Kramatorsk, Luhansk, and Molochne), but it is possible to restore them theoretically.

Trolleybus networks are more preferable, where there were 45 networks historically, 41 networks remained active, and traffic was suspended only on 4 networks in the eastern part of the country (Dobropilia, Stakhanov, Toreck, Vuhlehirsk). The list is supplemented by three metro networks (Kyiv, Kharkiv, and since 1995 – also Dnipro). The construction of the fourth metro network in Donetsk has never been completed, and the metro in Odessa remained in the sphere of plans only.

Ukrainian public transport is still rarely addressed in academic literature, especially in English. The barrier to conduct research is primarily and predominantly the poor availability of data, documents from the 1990s, and for foreigners – it is additionally the language and the alphabet. The basis of most of the research in Ukraine is an encyclopaedic guide on urban electric transport (Tarkhov *et al.*, 2010), a study on the history of Kyiv trolleybuses (Kozlov and Mashkevych, 2009) and a monograph on Ukrainian trolleybuses (Bogodistyj *et al.*, 2016). M. Rechłowicz (2016) wrote about the problems of the Donbas tram networks against the background of Poland and the Czech Republic. Research on the economic aspects of the functioning of urban transport in Ukraine was carried out by, e.g. O. Yu. Palant (2016, 2018).

## 2. DEFINITION OF TRANSPORT POLICY

Public policy can be described as the overall framework within which government actions are undertaken to achieve public goals (Cochran and Malone, 2014). Transport policy is included in the group of public policies. Transport strategy and policy embraces the collection of data and its transformation, the formation of policy objectives, the establishment of institutional structures to carry out these goals, the creation of the resources for these institutions, the carrying out of actions, and the policing and monitoring of outcomes (Button and Hensher, 2005). Sustainable transport is the intersection of three major domains: planning and policy factors, background factors, and technical and infrastructure factors (Schiller, Kenworthy, 2018, p. 263).

In the literature on the instruments of public policies, three perspectives can be distinguished: institutional, normative, and tool-based (Hood, 2008). Therefore, we considered transport policy in three aspects (Schubert, 2004): in the institutional dimension (*polity*), through offices, institutions or institutionalised forums for dialogue, in the process dimension (*politics*) which is a practical implementation of the objectives of sectoral policies through the decision-making process and the implementation thereof, and substantive policy conditions (*policy*), mainly contained in strategic and implementation documents.

In the theory of transport policies the following objectives occupy prominent places: economic efficiency, reflected in the increased competitiveness of regions through an improvement in accessibility and connectivity; social equity, reflected in more equal opportunities for better access both to transport infrastructure and public transport; and environmental sustainability, reflected in greater emphasis on coping with the negative outcomes of the transport sector, such as pollution, noise, landscape decay, congestion, and lack of safety (Button and Hensher, 2005).

One of the most important modern challenges of creating transport policy in cities is the problem of the growing role of personal motorisation. Within a few decades, urban areas across the world, both in developed and developing countries, have become increasingly automobile-dominated and less sustainable (Pojani, Stead, 2015). The contemporary requirement of transport policies is sustainable development of all transport. According to modern scientific literature there are a lot of tools and solutions helping to create such a policy (Attard and Shiftan, 2015; Faulin *et al.*, 2018; Hutton, 2013; Schiller and Kenworthy, 2018). Although some researchers have doubts whether sustainable transport policy is really sustainable (Eliasson and Proost, 2015), one of the most important goals of transport policies should be to reduce greenhouse gas emissions from the transport sector. The implementation of such assumptions is possible by increasing the role of urban electric transport in public transport mobility.

Among the basic criteria for evaluating public policies used by international organizations, such as the World Bank or the UN, the most attention is paid to:

relevance, efficiency, effectiveness, utility, sustainability, and impact. Additional criteria can be: deadweight, additionality, displacement, double-counting, substitution, and the gross and net effect (Turowski, 2014). Evaluative questions shall be constructed at different levels: descriptive, causal, normative, predictive, and critical (The evaluation of socio-economic development, 2003).

Therefore, one shall focus on the measures taken in the field of urban electric transport in Ukraine from yet another point of view: can they, in the understanding of public policy theory, actually be considered a policy, or is the actual policy of transport a lack of this policy.

### **3. LEGAL ASPECTS OF THE OPERATION OF URBAN ELECTRIC TRANSPORT IN UKRAINE**

In the first years of Ukraine functioning as an independent state, there were legal regulations and norms adopted in the times of the former USSR. Only in subsequent years, new legal acts were created as needed. One of the oldest legal acts concerning urban electric transport in Ukraine from the 1990s is the Transport Act (Zakon Ukrainy pro transport, 1994). A review of the documents from those years shows at the same time that, following the USSR model, the Ukrainian state still centrally wanted a system of a number of legal acts of varying significance to regulate all the areas of social and economic life.

According to the Act on urban electric transport (2004), the state policy in the field of urban electric transport is based on the accessibility of transport services for all population groups, the priority of urban electric transport development in cities with high levels of environmental pollution and spa regions, creating favourable conditions for the development of the production of domestic rolling stock and the profitability of carriers' operations.

This policy is to be implemented through appropriate legal regulations, state supervision over the technical condition of infrastructure and rolling stock, traffic safety, supporting investment and innovative projects, domestic rolling stock manufacturers, and ensuring the protection of passenger rights. Entities responsible for the implementation of this policy are the local government administration authorities and the local government which are supposed to organise urban electric transport according to the directions set out in the Act. The issue of financing comes down solely and exclusively to the general record about funds from the state budget, from local budgets, and other unspecified sources.

Municipal electric transport is organised by cities in the form of municipal enterprises. Most often, such companies serve one city, but there are exceptions, e.g. the trolleybus in the Crimea – one company operates 3 city networks, connected



by an inter-city line. The metro systems are also separate companies. An interesting exception was also a tram line operating in 1989–2014, in the village of Molochne, in Crimea (then the smallest tram network in Europe), which belonged to a sanatorium.

The most important strategic document for transport in Ukraine is the “National Transport Strategy of Ukraine 2030” for all types of transport. The provisions concerning urban electric transport included in the Strategy are, however, very general. The strategy plans to increase environmental safety of transport by incentives to use more environment friendly transport modes, including electric cars, electric public transport, such as metro, trams, trolleybuses, electric buses, and bicycles, but the strategy does not have any specific guidelines for achieving that task (Rozporjadzhennja vid 30.05.2018, № 430-r).

The following should be considered as the most important governmental executive programs for the development of urban public transport after 1991: the program for the development of national production of trams and trolleybuses (Postanova vid 1.07.1998), the concept for the development of urban electric transport for 2006–2015 (Rozporjadzhennja vid 15.06.2006, № 330-r), or the long-term program for the development of the metro network (Rozporjadzhennja vid 28.12.2011, № 1361-r). For Crimea, currently unrecognised by the international community as part of Russia, the trolleybus program on the inter-city line was of great importance, financed not only from the state budget, but also from the budget of the Autonomous Republic of Crimea (Postanovlenie s 20.10.2010, № 1911-5 / 10).

The comprehensive transport policy, based on the experience of Western European countries, indicates a number of instruments supporting the development of public transport. The instruments for influencing the users of personal transport (e.g. Stuart, 2005; Holger, 2010; Santos, Behrendt and Teytelboym, 2010) play an important role. Meanwhile, in the Ukrainian planning documents which include general plans for urban development, there is still more emphasis on the development of road infrastructure, more or less consciously preferring the position of cars in the transport system. Modern conceptions of the development of transport in urban areas, e.g. smart city or electromobility, are currently at a preliminary implementation stage only in major cities (Matyushenko and Pozdniakova, 2016).

#### **4. CURRENT PROBLEMS OF FUNCTIONING AND DEVELOPMENT OF URBAN ELECTRIC TRANSPORT IN UKRAINE**

Simultaneously, when there is the renaissance of tram in the Western European countries, particularly visible in France (Groneck and Schwandl, 2014; Konopacki-Maciuk, 2014; Boquet, 2017), suspensions or closures of several tram and trolleybus net-

works are observed in Ukraine. There are some disturbing reports from several other cities that urban electric transport still functions but solely on a small part of the network, in addition, further functioning of these systems for technical and economic reasons is uncertain. What, then, was decisive in terms of the tendencies of the development of urban electric transport that made it different from Western Europe?

One of the basic problems limiting the possibilities of shaping public transport opportunities in many cities is the lack of efficient rolling stock. Due to the lack of resources and limited support possibilities from local budgets, tram and trolley rolling stock are exchanged annually only at 10% of the needed minimum. About 90% of the rolling stock has already exceeded its life cycles and is subject to systematic withdrawal (Rozporjadzhennja vid 15.06.2006, № 330-r). As a result, in both tram and trolleybus transport, the number of vehicles per 1 km of network has been decreasing for the last 25 years, which directly translates into the accessibility and availability of that means of transport. It was one of the factors which impact the total number of passengers of urban electric transport in Ukraine (Table 1).

Table 1. Changes in the number of passengers in urban electric transport in Ukraine

Type of transport	1991	1997	2003	2009	2016
number of passengers (in millions)					
Tramway	1,812.2	1,265.3	1,132.2	787.0	694.0
Trolleybus	2,906.6	2,388.1	1,920.7	1,283.3	1,038.7
Metro	595.3	507.9	872.8	751.9	698.4
Total	5,314.1	4,161.3	3,925.7	2,822.2	2,431.1
change dynamics in per cent (1991 = 100%)					
Tramway	100.0	69.8	62.5	43.4	38.3
Trolleybus	100.0	82.2	66.1	44.2	35.7
Metro	100.0	85.3	146.6	126.3	117.3
Total	100.0	78.3	73.9	53.1	45.7

Source: State Statistics Service of Ukraine.

In 1991–2016, only 195 new domestic tram cars and 249 foreign ones were purchased. At the same time, over 500 second-hand cars were imported. Much more new trolleybuses were purchased. In the corresponding period, 2,258 Ukrainian and around 1,500 foreign vehicles were purchased, mostly Russian. The shortages in the rolling stock were supplemented with second-hand trolleybuses from other countries – within nearly 25 years, almost 300 used vehicles have been brought to Ukraine. Most of the operated rolling stock consists regular vehicles. Electric buses are operated only in Lviv and Vinnytsia, hybrid trolleybuses using alternative power sources (traction batteries, super capacitors or combustion power



generator) are operated in 8 cities: Chernivtsi, Dnipro, Kramatorsk, Kremenchuk, Kryvyi Rih, Odesa, Rivne, and Sevastopol.

The differences in the number of rolling stock throughout the country are extreme. In 1991–2016, the number of trams decreased from 4,988 to 2,222 vehicles (54% fewer), trolleybuses – from 7,399 to 3,373 vehicles (49% fewer). The number of metro carriages increased by only a half – from 795 to 1,195 (Tarkhov *et al.* 2010, Urban Electric Transit). The production of trams and trolleybuses in Ukraine, in the aspect of transport fleet capability, has been discussed extensively by Soczówka, Rudakevych (2018).

All large state investment programs in public transport in Ukraine were to a large extent of the character of interventional ad hoc measures and are often implemented solely and exclusively in selected cities. For instance, at the end of the 1990s, a large intervention program was created to co-finance the domestic production of tram and trolleybus rolling stock (Postanova vid 1.07.1998, № 992). In 2006–2008 a co-financing program was fulfilled for the purchase of a new tram and trolleybus rolling stock, commonly referred to as “50 to 50” (Postanova vid 29.12.2006, № 1855). When buying new Ukrainian production vehicles, 50% of the cost was covered by the state, while the remaining half was covered by municipal budgets. The program was suspended due to the financial crisis. The investments in the form of purchase of domestic rolling stock for the UEFA Euro 2012 only applied to four cities in which the competition was held (Postanova vid 14.04.2010, № 357). The purchase of the rolling stock was also co-financed by large industrial plants (e.g., Severodonetsk, Cherkasy).

Currently, Ukraine is implementing another aid program in public transport, this time co-financed by the European Bank for Reconstruction and Development, worth EUR 400 million. Half of the amount is a preferential loan, half comes from local budgets. The national program is implemented independently of local programs. It supports the modernisation and expansion of tram and trolleybus infrastructures, as well as the purchase of a new rolling stock. Significant effects of the implementation of the program also include the reduction of electricity consumption and carbon dioxide emissions.

Nevertheless, the gradual regression of public transport did not mean that there were no investments in the development of the network whatsoever. New sections of the network were built, especially in the 1990s, when the economy of Ukraine was still in a relatively good condition. In independent Ukraine, e.g. Dnipro metro was built, the metro was extended in Kyiv and Kharkiv, a fast tram line in Kryvyi Rih was established, the left river bank tram network in Kiev was expanded, a new trolleybus network was established in Kerch on the Crimean peninsula, and many cities put into operation new trolleybus network sections. Many of these investments were co-financed from the central budget.

In 1991–2016, the total length of tram lines in Ukraine decreased from 2,171 to 1,776 km (approximately 18%), while the trolleybus lines increased – from 4,044

to 4,349 km (up by 8%) and underground lines increased – from 70 to 114 km (up by 63%) (Tarkhov *et al.*, 2010; Urban Electric Transit and own calculations).

A serious problem in the functioning of the public transport system in Ukraine is the large number of passengers with entitlement to free, or reduced fare. Approximately 30 categories of passengers are entitled to free rides, but their number may vary from city to city. Most of the discounts were approved at the level of central government (parliament, government) in the first years of Ukrainian independence. There are also several additional categories of travellers entitled to discounts granted by local authorities.

The problem of free rides perfectly shows the difficult dependence of local enterprises on the state budget as part of the broadly understood public policies. The discounts were set by the central authorities, but in many cases they were not sufficiently compensated for public transport operators. Compensations for free or discounted rides were only partially paid, which steadily worsened the financial situations of local carriers. Analysing the system of urban transport, Palant (2014) calculated that those compensations covered only 30–40% of actual losses incurred by the companies.

Theoretically, the discounts were supposed to help groups of people who were in a difficult economic situation, in practice they caused the opposite. The municipal companies which were in financial difficulties due to discounts and the lack of investment significantly limited the offer or ceased operations, as a result these groups of citizens found themselves in an even more difficult situation – the remaining private carriers (the so-called marshrutkas) are more expensive, they offer a lower standard of travel, and are reluctant to accept any discounts. Recently, shared taxi service has been completed and it has been approved with some planning or sustainable policy (Vozyanov, 2018).

The obligation to pay financial compensation to businesses for free travel in the past was transferred onto various ministries. In February 2016, further changes were introduced to the budgetary and fiscal legislation of Ukraine. The obligation to compensate for free and reduced rides was transferred from the central authorities to local governments. Some cities attempt to register such passengers, however, this process sometimes violates the permissible rights, which leads to court cases.

However, a SWOT analysis (Table 2), clearly reveals the negative perspective of the development of urban electric transport systems in Ukraine – the advantage of the weaknesses over the strengths and the threats over the opportunities. It indicates a number of serious problems that are difficult to solve in a short time without clearly investing in the entire industry. An additional negative role is played by macroeconomic factors – currently it is the military and economic conflict with Russia, affecting the entire economy and mass economic migrations caused by the attractiveness of EU labour markets. The SWOT analysis for urban electric transport was carried out by Dyvinec' (2015). On many levels, the conclusions and insights from both analyses are convergent.

Table 2. SWOT analysis of the situation of urban electric transport in Ukraine

Strengths	Weaknesses
<ul style="list-style-type: none"> <li>• Well-developed spatially urban electric transport network in large cities (servicing a large area of the city)</li> <li>• Good service for historically developed industrial districts</li> <li>• Well-maintained and overhauled infrastructure in some cities</li> <li>• Habits of city dwellers to use urban electric transport, e.g. due to the low level of affluence and discounts</li> <li>• Higher transport capacity and lower prices compared to marshrutkas</li> <li>• The cities systematically purchase new rolling stock, more often – trolleybuses, less often – trams or metro cars</li> <li>• After regaining independence, new sections were built on many trolleybus networks, and several tram lines were built</li> </ul>	<ul style="list-style-type: none"> <li>• The shape of many public transport networks does not correspond to the modern transport needs of cities</li> <li>• High degree of depletion of rolling stock and infrastructure on most networks, especially in the eastern part of the country</li> <li>• In many cities, there is a shortage of funds for infrastructure investments, even of a replacement character</li> <li>• Not all cities purchase rolling stock in sufficient quantities; rolling stock shortages are supplemented with second-hand rolling stock from the EU and Switzerland</li> <li>• High energy consumption of old infrastructure and old rolling stock – increase in operating costs</li> <li>• Many years of underinvestment in the urban transport industry by city authorities</li> <li>• Unattractive price plans, promoting direct and single rides, too many people entitled to free travel</li> <li>• Lack of passenger information at bus stops, and often also on the Internet</li> <li>• Unfair competition of private carriers, often treated preferentially by city authorities</li> <li>• Low transport speed in relation to individual transport means and marshrutkas</li> </ul>
Opportunities	Threats
<ul style="list-style-type: none"> <li>• Metro systems, as well as a part of tram and trolleybus lines, create the possibility of efficient passenger transport</li> <li>• The possibility of using international credit programs to facilitate investments in public transport</li> <li>• The increase in the popularity of urban electric transport as a result of the increase of ecological awareness of residents</li> <li>• The use of electric traction reduces low stack emissions in cities</li> <li>• Increased possibility of using flexible price plan solutions, along with technological progress (popularity of smartphones, proximity cards, etc.)</li> </ul>	<ul style="list-style-type: none"> <li>• Lack of awareness or low awareness of the city authorities about the role of public transport in the functioning and development of a city</li> <li>• Growing level of motorisation, causing a natural drop in the number of public transport passengers</li> <li>• Low management competences, no strategy and no ideas for the development of urban electric transport</li> <li>• Preference for road investments as an antidote to transport problems in cities</li> <li>• Decreasing prestige of poor-quality urban electricity transport – in many centres it serves mainly a community function</li> </ul>

Opportunities	Threats
<ul style="list-style-type: none"> <li>• Possession of domestic rolling stock manufacturers with sufficient experience in the production of trams, trolleybuses, as well as repairs of metro cars</li> <li>• A new way of contracting services is introduced by separating the functions of an organiser and a carrier (billing carriers from the quantity and quality of services)</li> </ul>	<ul style="list-style-type: none"> <li>• Low quality of rolling stock and elements of national production infrastructure – limited durability of investments made</li> <li>• Lack of transparency in management, imperfection of public procurement procedures and conducting investments creating a high risk of corruption</li> <li>• Higher remuneration for drivers and mechanics in neighbouring EU states – labour migration</li> <li>• Obligation to compensate for the right to free travel from the city budgets limits the possibilities of investment</li> </ul>

Source: own work.

## 5. SYNTHETIC INDICATOR OF CHANGES IN URBAN ELECTRIC TRANSPORT

The directions of the changes in the urban electric transport system in Ukraine were examined using a synthetic indicator illustrating the development or regression of these systems. The main problem in the construction of own indicators by authors was the limited amount of available data for 25-years research period. This indicator included a total of 9 features (three analogous features for the metro, for the tram and for the trolleybus): the network density per 1 sq. km of a city, the number of vehicles (or carriages) per 1,000 inhabitants, and the percentage of restored rolling stock in the last 6 or 7 years. In Ukrainian conditions, the tram and trolleybus only partially play a substitutive role in relation to the metro, but very often trams play a substitutive role in relation to trolleybuses and vice versa.

The basic data was collected for the following years: 1991 (year of regaining independence), 1997, 2003, 2009, and 2016. The main source of the data for tramway, trolleybus and metro was the publication of Tarkhov *et al.* (2010). Further and more recent data was completed by own calculations based on the rolling stock database available on the website of Urban Electric Transit and the calculations on the base of city maps. In the case of rolling stock, the data for 1985–1990 was also taken into account. The data for the number of inhabitants and areas of cities was taken from recourses of the State Statistics Service of Ukraine – compilation from national and regional statistics databases. An exception was made in the case of the Crimean network: the number of inhabitants and areas was included in all the cities and villages along the interurban trolleybus network, because this system combines three functions at the same time: of urban, suburban, and interurban transport.

The indicator constructed in such way was designed to assess, in a representative and comparable manner, the changes on individual networks with limited access to long-term, comparable data. The maximum, minimum and average values are presented in Table 3. There is no possibility to obtain a lot of data, for instance about finances (revenues, subsidies, financial results, etc.) or employment in individual cities or companies. The collected data – each feature separately – were subjected to standardisation, in relation to the best value occurring in the 25-year period in all analysed networks. Every feature, after standardisation, assumed a value from 0 to 1, and the value of the indicator is the sum of standardised values of features.

The theoretical value of a standardised indicator should be within the range from 0 to 9. In practice, the empirical values were significantly lower. Firstly, the metro operates only in three cities. Secondly, in the cities where tram systems are better developed, trolleybus systems are less developed and vice versa. Thirdly, with the development of the metro, changes are made to the surface route layout, which eliminates the duplication of connections, and the tram and trolleybus serve a commuting purpose to the metro. In the centres of Kyiv and Kharkiv a lot of sections of tram networks were closed down with the development of the metro network. Finally, there are networks where, in relation to the size of the city, urban electric transport already functions in a symbolic, even rudimentary manner. In the case of the number of vehicles in relation to the number of inhabitants, the second variable was also responsible for the changes in the value of the indicator. The total population in cities with urban electric transport in Ukraine decreased from 20.0 million in 1991 to 18.2 million in 2016. The exception was Kyiv and Sevastopol, where the population within the 25 years increased by 10%.

The conducted research indicated that in the years 1991–2016 the average value for all networks in Ukraine of the constructed by authors synthetic indicator decreased by half, i.e. it fell from 1.63 to 0.84 (Fig. 1). Yet the speed of regression within 25 years was uneven. Until 2003, practically all networks experienced a decrease. Later, there was a certain polarisation – some cities continued the downward trend, and some, as a result of investments, made small progress (Fig. 2).

The biggest drop in the 25 years (from 2.21 to 0.00) was experienced by Stakhanov, in which a tram and a trolleybus were liquidated in a short time. The situation in Kryvyi Rih also deteriorated considerably (decrease by 1.64). There was a slight improvement only in 4 networks – Crimean trolleybus (0.24 more), Kerch (0.21 more – new network), Bila Tserkva (0.09 more), and Kyiv (0.01 more). Kyiv is an especially interesting case, where despite large investments, an increase in the indicator was of a symbolic character.

The synthetic indicator also revealed that there were several networks threatened with decommissioning in the coming years; these were trolleybus networks: Antratsyt (0.12), Makiivka (0.20), Lysychansk (0.29), Khartsyzsk (0.35), Sloviansk (0.40), trolleybus station Horlivka (0.30), and tram station Konotop (0.38).

With the exception of Konotop, all of the above networks are located in the eastern part of Ukraine. The Crimean Peninsula should be considered a special case, as Russia considers it part of its territory. Despite the low value of the indicator of two Crimean networks – trolleybus in Kerch (0.21) and tram in Evpatoria (0.25), the political factor will play a major role and, for propaganda reasons, these networks will be adequately invested and will continue to function.

The regress of urban electric transport is not characteristic only for Ukraine, but for all former USSR republic, with the exception of the Baltic states with access to EU funds, as well as Belarus. After 25 years of economic transformation, at the end of 2016 in Russia, out of 72 tram networks, 11 were liquidated, and of 91 trolleybus networks – 11 were liquidated. In Kazakhstan, there are only 3 out of 5 tram networks, and of the 9 trolleybus – only 1 (*Atlas of Urban Electric Transport ...*, 2016, Urban Electric Transit). Successive networks are threatened by suspension and liquidation. The reasons for liquidation include, obviously: financial problems of companies, poor condition of technical infrastructure, rolling stock, etc.

Table 3. Minimum and maximum values of indicators included in the synthetic index

Indicator	Max. value City	Year*	Min. value City	Year*
Tram				
Network density [km / sq. km]	1.32 – Odessa	1997, 2003	0.07 – Yenakievo	1991
Number of vehicles per 1,000 people	1.00 – Avdiivka	1991, 1997	0.06 – Horlivka	2016
New rolling stock – the last 6–7 years (%)	51.7 – Kryvyi Rih	1985–1991	0.00 – 17 cities	2010–2016
Trolleybus				
Network density [km / sq. km]	2.60 – Lutsk	2016	0.09 – Makiivka	since 2003
Number of vehicles per 1,000 people	0.97 – Alchevsk	1991	0.04 – Antratsyt	2016
New rolling stock – the last 6–7 years (%)	59.2 – Crimean trolleybus	2010–2016	0.00 – 10 cities	2010–2016
Metro				
Network density [km / sq. km]	11.00 – Kharkiv	2016	1.93 – Dnipro	since 1997
Number of vehicles per 1,000 people	0.28 – Kyiv	2016	0.04 – Dnipro	since 1997
New rolling stock – the last 6–7 years (%)	18.9 – Kyiv	1991	0.0 – Dnipro	since 1997

\* in the study, the following years were taken into account: 1991, 1997, 2003, 2009, 2016

Source: own work.



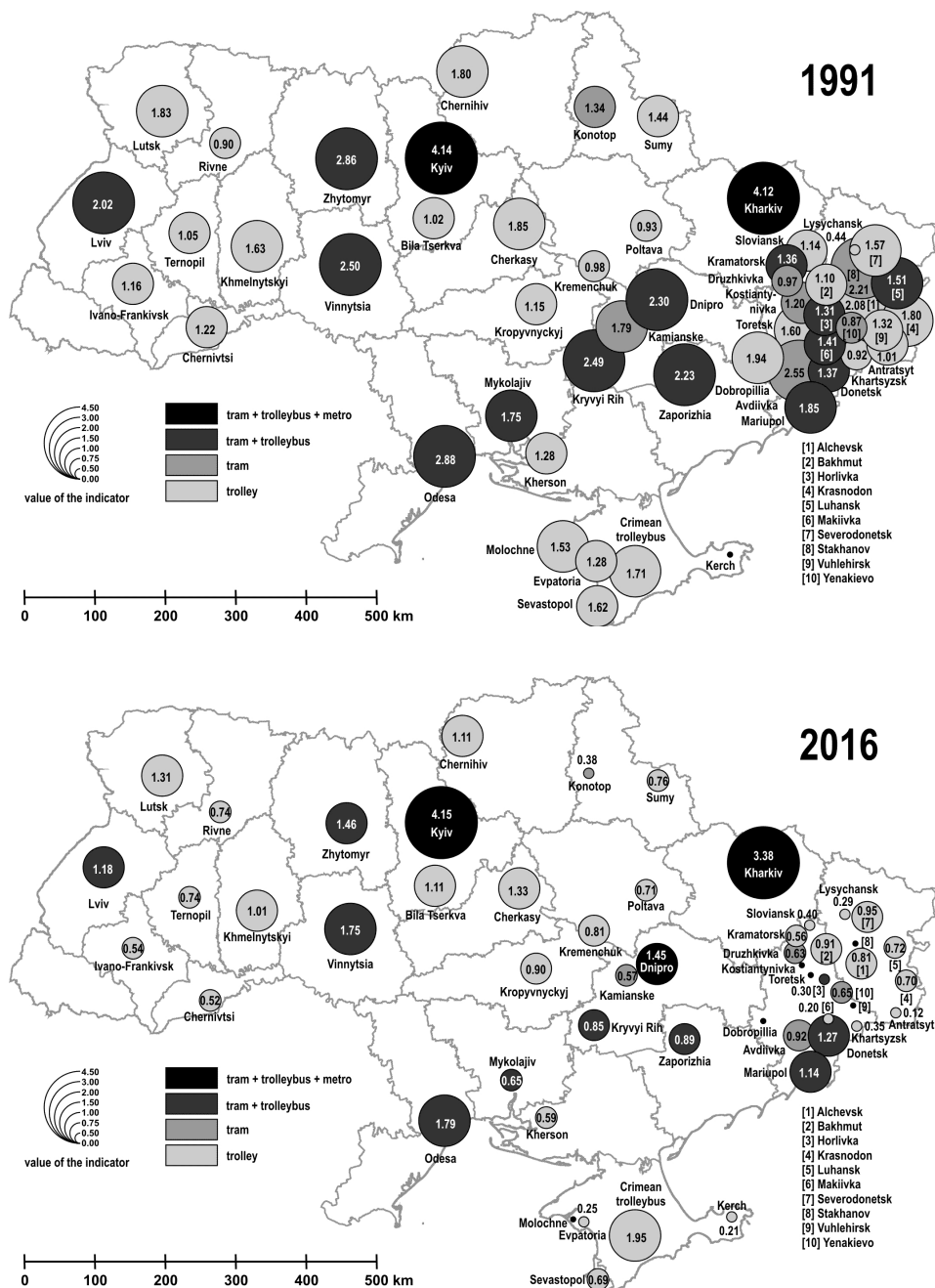


Fig. 1. Synthetic indicator of the development of urban electric transport in 1991 and 2016

Source: own work.

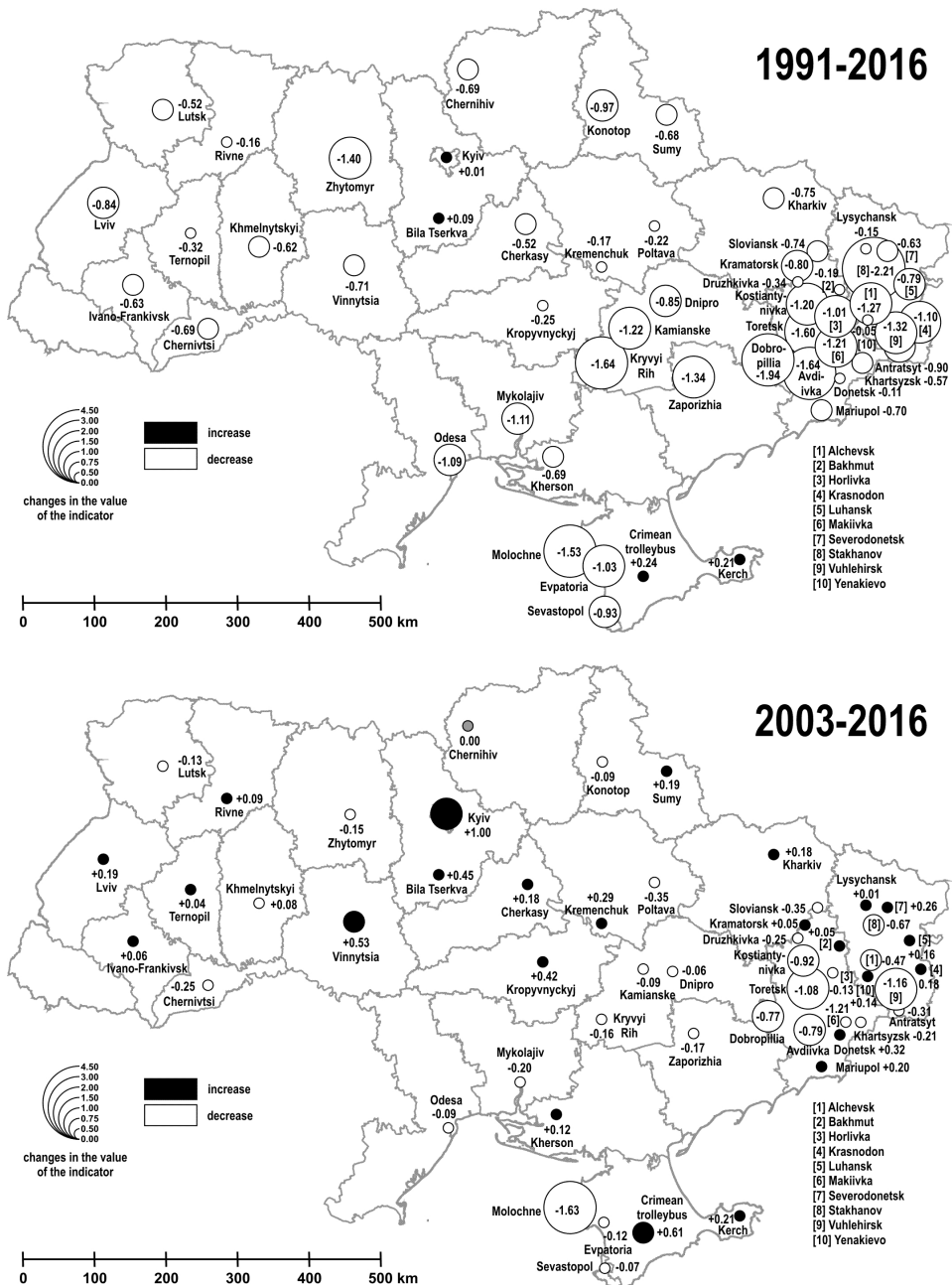


Fig. 2. Changes in the value of the synthetic indicator of the development of urban electric transport in the years 1991–2016 and in the years 2003–2016

Source: own work.

## 6. CONCLUSIONS

The directions of transport policy designated by key legal acts (laws, strategy) generally guarantee the citizens of Ukraine public, ecological, and sustainable public transport in accordance with the principles of its organisation in the countries of Western Europe. In this system, certainly, public transport should play an appropriate role. However, it is a theoretical system because its creators have not created the right conditions for its implementation.

The division of financial tasks between the state budget and city budgets is a classic mechanism of mutual transfer of responsibility. The basic problem is the long-term underfunding of urban transport infrastructure and companies, which translates into an increasingly difficult economic situation. It has often happened in the modern history of companies urban electric transport that employees did not receive salaries or received them only in part. Often a lot of vehicles were out of service for a long time due to the lack of financial recourses for the purchase of spare parts. At the same time, a high degree of decapitalisation, progressive regression (closing of routes, *dismantling* of infrastructure, lack of rolling stock), combined with a small share of trams and trolleybuses in urban transport, puts the future of several systems in question. Another difficult challenge is the creation of stable mechanisms of long-term financing in conditions of the unstable economic situation in Ukraine.

In the development of public transport, large state programs still play a major role. Local self-governments, except for the richest cities, are not able to finance large transport investments. Bearing in mind the imposed obligations of shaping the local transport policy, proper implementation of those tasks requires the strengthening of the financial situation of local governments. The nature of municipal electric mobility in Ukraine, based on central regulations and their local implementation, means that this process can take various forms, and the differences can be quite significant. Ensuring mobility is a condition for the development of both cities and regions. It allows the allocation of resources on the labour market, and also determines the intensity of interpersonal relations.

In 1991–2016, in the vast majority of Ukrainian cities there was a regression of urban electric transport. It was of a bipartite nature: in the first years it basically applied to all networks, later a polarisation of cities took place and the situation improved due to the investment activities undertaken on parts of the network. The general economic and political situation, in particular the difficult economic relations with Russia, and from 2014 – the separatist conflict in eastern Ukraine – had an impact on this state of affairs. It shall also be remembered that, in contrast to the countries of Central Europe and the Baltic states, Ukraine has never had access to such large financial resources to raise the level of its development.

The regression rate is not the same across the country; it is particularly visible in the eastern part of Ukraine, i.e. in the industrial area of Donbas and Krivbas. Those are particularly problematic, as their local economies are based on hard coal mining, mining and metallurgy, and other heavy industries. Many of the plants is unprofitable (Swain, 2007; The Coal Sector..., 2003), but at the same time they are often the only major local employers. Unemployment was a problem of the cities for many years. The local economy requires large financial expenditures for restructuring, much larger than the financial possibilities of the municipal and peripheral governments. All of those problems have found a global reflection in the condition of urban electric transport.

Since the beginning of the 1990s, in Ukraine, as in most of the post-socialist countries, the number of passenger cars has been systematically growing. Initially, the problems of transport congestion in cities were solved by increasing the capacity of the road system, even at the cost of trams and trolleybuses. It is only recently that car traffic restrictions in districts in city centres or payment for parking have been applied in some cities. However, urban development strategies and other analogous documents lack real elements and the instruments of sustainable development.

The uncoordinated and often ad hoc measures undertaken at various levels in the context of the assumptions of public policy are difficult to assess as a transport policy, actually oriented towards sustainable urban development and shaping sustainable transport systems. There is a clear dissonance between the provisions regarding the role of urban electric transport in the transport system, and the actions taken and the applied transport policy instruments. The authorities of Ukrainian cities, aiming to satisfy car users through road investments, and at the same time in a conflict-free way developing or maintaining urban electric transport, fall into the classic vicious circle of congestion. It is the mechanism when congestion puts strong pressure on road operators to increase their capacity. New capacity often temporarily results in a better quality of road transport. Users, through their modal choices of travelling by cars, cause more congestion and are negatively influencing on the urban transport system (Rodrigue, 2017).

The gap between the demand for transport occurring for many years on the market and the supply from urban electric transport is more or less efficiently filled by private bus carriers, servicing low-capacity rolling stock lines. Marshrutkas can be considered an area of negotiations (Vozyanov, 2018). Marshrutkas are not positively perceived by passengers due to the desire to maximize profits, unpunctuality, lack of training, improper servicing of the rolling stock, and a very low standard of travel (in rush hours, small vehicles are very overloaded). The limited availability of commercial financing in Ukraine, either as corporate debt or lease finance, to purchase new vehicles presents a significant obstacle to contracting with private operators for improved bus services (Sustainable Urban Transport for Kyiv..., 2016). Private carriers operate routes with the highest profitability, they create the wrong belief of politicians about the availability of public transport without subsidies from public funds.

Is, therefore, urban electric transport in Ukraine doomed to fail, following the model of tramlines being liquidated in Western Europe after the Second World War? Not necessarily, however, similarly to the transformation that took place in industry in highly developed countries (transitions from heavy industry to the industry of new technologies), a deep transformation of the transport system will be needed, involving the adaptation of urban electric transport systems to the modern transport needs of residents. Instead of the social assistance function for poor residents, efficiently operating urban electric transport should be an alternative to individual motorisation. However, it requires large financial outlays and general changes in the city planning concept.

Electric mobility is a global trend resulting from the search for alternatives to gradually depleting crude oil (e.g. Attias, 2017; Leal Filho and Kotter, 2015). Urban electric mobility will cover not only public communication, but various forms of energy storage and the widespread use of electric vehicles (Przybyłowski, 2018). According to the assumptions of *A European Strategy for Low-Emission Mobility* (2017), electric vehicles, used among other in the car-sharing model, integrated with intelligent power grids will in the future complement urban transport systems.

Presumably, Ukraine will soon join the group of countries in which electric mobility will gradually develop. For now, Ukraine is less developed in terms of electromobility compared to Western and Central Europe. Electric buses or hybrid trolleybuses popular in Europe are being tested only in a few cities. Spatially well-developed trolleybus networks in city centres, better knowledge in the field of exploitation of trolleybuses and lower purchase prices of trolleybuses compared to electric buses should predestine this type of transport in the development of electric public transport. Positive Czech and Polish experiences should be taken into account in the expansion of trolleybus networks based on hybrid trolleybuses.

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